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UNITED STATES
DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
R. R. SAYERS, DIRECTOR

INFORMATION CIRCULAR

REPORT OF PETROLEUM AND NATURAL-GAS DIVISION

FISCAL YEAR 1944

BY

R. A. CATTELL, H. P. WHEELER, JR., AND OTHERS

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REPORT OF PETROLEUM AND NATURAL-GAS DIVISION FISCAL YEAR 1944 1/

By R. A. Cattell, 2/ H. P. Wheeler, Jr. 3/ and others

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INTRODUCTION

Every finding of the year's work, obtained under stress to meet present objectives, contributed to postwar needs, because the very nature and constitution of petroleum and natural gas require that research be conducted along the same general lines whether the results are applied in peace or war. More than 40 reports were submitted to the Petroleum Administration for War and others concerned with (1) evaluation of crude oils to determine their content of aviation-gasoline base stock, (2) evaluation of base stocks for blending with high-octane, synthetically manufactured components, (3) analyses of naphthas to determine their content of various types of hydrocarbons, such as benzene and toluene, and (4) the improvement of quality of marginal base stocks to meet future requirements of aviation gasoline. This upgrading of marginal stocks is being attained by selective distillation and chemical and catalytic removal of sulfur compounds. Asphalts were studied with respect to the characteristics of their various constituents in order to compound them in the same way that aviation fuels now are being "built" to meet exacting requirements.

The work previously initiated to give the industry fundamental data on thermodynamics of hydrocarbons progressed satisfactorily, and the heats of combustion of 10 hydrocarbons in the lubricating oil range of petroleum were determined. Thermodynamic data requiring highly specialized techniques are so broad in application that their commercial usefulness is not yet fully appreciated.

Emphasis was continued on primary extraction of petroleum in condensate fields to determine the quality, quantity, and nature of the reservoir components for use in aviation gasoline. Five engineering reports on Gulf

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Coast fields and three others on the flow characteristics and properties of the fluids in separate reservoirs, as determined with the mobile field laboratory, met the needs of the Petroleum Administration for War and the operators for specific data. Also, the research on productivity of wells, cycling possibilities, and properties of fluids from the respective reservoirs gave threshold entrance to an important phase of the national fuel economy of the futura, when many of these fields will become reserves of relatively dry recycled gas. Subsurface surveys were made in two important Rocky Mountain fields, where plans to operate them at high rates of production could not be formulated until the Bureau supplied the acutely needed data on the reservoirs and the reservoir fluids. Continuing research on well spacing gave many data, which were analyzed to obtain a possible correlation of oil recovery and well spacing on the basis of A. P. I. gravity of the reservoir oil.

The application of stimulative methods, such as air and gas repressuring and water flooding in fields where the energy to move the oil through the porous rocks must be supplied artificially, and the removal of oil from impregnated sands in surface and near-surface deposits were outstanding contributions. In the Appalachian region, knowledge of modern engineering practices was disseminated among the 15,000 oil operators, and a report on observed operations of a project in Venango County, Pa., where horizontal holes are being drilled into the oil sand from a vertical shaft, will be published shortly. An innovation to reduce the cost of lifting oil was instituted by experimentation with siphons that flow oil from vertical wells on properties where air and gas are being injected. Other accomplishments include surveys of water-flooding projects in Oklahoma, Kansas, and Illinois, a study of air and gas injection in Illinois, and collection of water-flooding data in limestone reservoirs - a subject on which there is a dearth of information. Tests in a small laboratory plant continued on the removal of oil from impregnated sandstones by the controlled use of petroleum solvents and aqueous solutions of sodium silicate. The percentage recovery of oil depends on the extraction treatment, the temperature of the solutions, and the length of time the sand is in contact with them.

A field pilot plant was built, and initial tests were made to remove micro-crystalline wax from tank bottoms, which in the Mid-Continent area alone accumulate at the rate of 3 million barrels a year. Laboratory and field tests were of great value to operators in improving the wall-building and water-loss properties of drilling fluids, thus effecting economies in the use of steel casing, and showed many innovations in mixing and controlling oil-base drilling fluids.

Helium-production facilities, expanded by the completion of three new plants, have met all helium requirements of the armed forces. Also, large quantities now are available to commercial purchasers to use in such outstanding processes as welding magnesium, aluminum, and alloy steels. Furthermore, ample quantities are available for developing new processes and uses. The Bureau's conservation program - processing gas from fields that supply commercial fuel markets, and from which helium would otherwise be lost forever, and the placing of excess helium in underground storage - will assure ample supplies of helium for postwar industrial activities and medical use.

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The continuing research program pertaining to the efficiency of oil and gas extraction and better methods for making petroleum and its products readily available at reasonable cost has been increased in scope by initiation of an oil-shale program under the Synthetic Liquid Fuels Act (Public Law 290).

The Petroleum and Natural Gas Division has experiment stations at Bartlesville, Okla., and Laramie, Wyo.; field offices at Dallas, Tex., and Franklin, Pa.; a field office and laboratory at San Francisco, Calif.; helium plants at Exell, Tex., Otis and Cunningham, Kans., and Shiprock, New Mex.; and a helium plant, engineering office, and experimental laboratory at Amarillo, Tex.

ACKNOWLEDGMENTS

Virtually all technical members of the Division contributed in some way to the preparation of this report. Specific information on work accomplished under their supervision was supplied by the following supervising engineers:

N. A. C. Smith, Petroleum Experiment Station, Bartlesville, Okla.
H. P. Rue, Petroleum Experiment Station, Laramie, Wyo.
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RESEARCH ON PETROLEUM CHEMISTRY AND REFINING

WAR RESEARCH ON AVIATION GASOLINE AND ITS COMPONENT HYDROCARBONS

During the fiscal year, the Petroleum Chemistry and Refining Section conducted intensive research on aviation gasoline. The work had two main objectives: (1) To obtain information that might lead to increasing the the quantity of aviation gasoline and (2) to obtain information that might aid in improving its quality. As the war progressed, the two objectives changed in importance, quality taking precedence over greater quantity. The reversal was gradual, and results achieved in increasing yield provided valuable information as to improving quality.

In carrying out the work, approximately 35 to 40 professional and subprofessional employees were required together with several employees in the clerical and custodial groups. The organization was subdivided into several small groups, each having a definite function. One group, consisting of about 10 persons, was concerned largely with the processing of crude oils and naphthas to provide material for subsequent engine tests and analytical work. A second group was concerned primarily with the analysis of hydrocarbon mixtures and the preparation of blends of aviation base stocks with high-octane blending agents. This group usually consisted of about 12 employees. As one of the major functions of the work was to determine the engine performance of hydrocarbons in fuels, one group had for its prime

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purpose the evaluation of various samples by means of engine tests, and this work alone required the services of seven employees. In order to have full knowledge of the characteristics of the various samples that were prepared, many routine tests were required - determinations of sulfur and tetraethyl-lead content, D-86 distillations, vapor pressures, and other pertinent inspections. A fourth group of six was continually at work performing those routine tests. A fifth group, consisting of two men but augmented at times by members of the other groups, spent its time preparing reports by which the data were made available promptly to the petroleum industry and Government organizations.

As an example of some of the work that was accomplished, probably about 2,000 man-hours were expended by the members of one group in performing hydrocarbon analyses of aviation base stocks, only one of the several problems with which that group was concerned. The engine-test group expended 6,103 man-hours in engine operation alone, exclusive of all time required for overhauling engines, making calculations, preparing test reports, and preparing samples for test. In addition to making complete analyses on 175 crude oils by the Hempel method, members of the fourth group made 3,451 miscellaneous determinations on the samples submitted.

These figures cover only a part of the work which the various groups were called upon to do, because, in addition to regular reports on evaluations of base stocks and crude oils, many data were prepared for special committees - including the A.G.A.C. and the A.S.T.M. Committee D-2, Subcommittee XXV, on developing methods of hydrocarbon analyses. It is of interest to note that 51 reports were issued on material originating from 7 States. The reports are divided among the States as follows: Texas, 26; California, 12; Louisiana, 6; New Mexico, 3; Illinois, 2; and one each from Oklahoma and Kansas. In addition, four special reports dealing with analytical methods for hydrocarbons were issued. If the average size of a technical paper is considered to be 30 pages, the 24 reports (306 legal-size pages) issued on the blending values of aviation base stocks are equivalent to 10 technical papers. If the four special analytical reports and one Report of Investigations, which under normal conditions would have been issued as technical papers, are added, it can be seen that part of the work released during the year by the petroleum chemistry and refining groups is equivalent to 15 technical papers. Because the reports contain information that might aid the enemy, they cannot be distributed freely at this time. The Bureau of Mines sincerely hopes to release the information to the general public at the end of the war.

Aviation gasoline is a blend of synthetic and natural products, both of which are prepared from petroleum. Whereas, in the first World War aviation gasoline was largely a straight-run natural product, today's aircraft engines require that straight-run material be blended with synthetic products to make a satisfactory fuel. However, synthetic materials are relatively scarce and they are expensive. Therefore, optimum use of natural products is essential. Such use of natural products requires complete knowledge of their characteristics, and improvements in quantity and quality of aviation fuel can come only from a thorough knowledge of materials that

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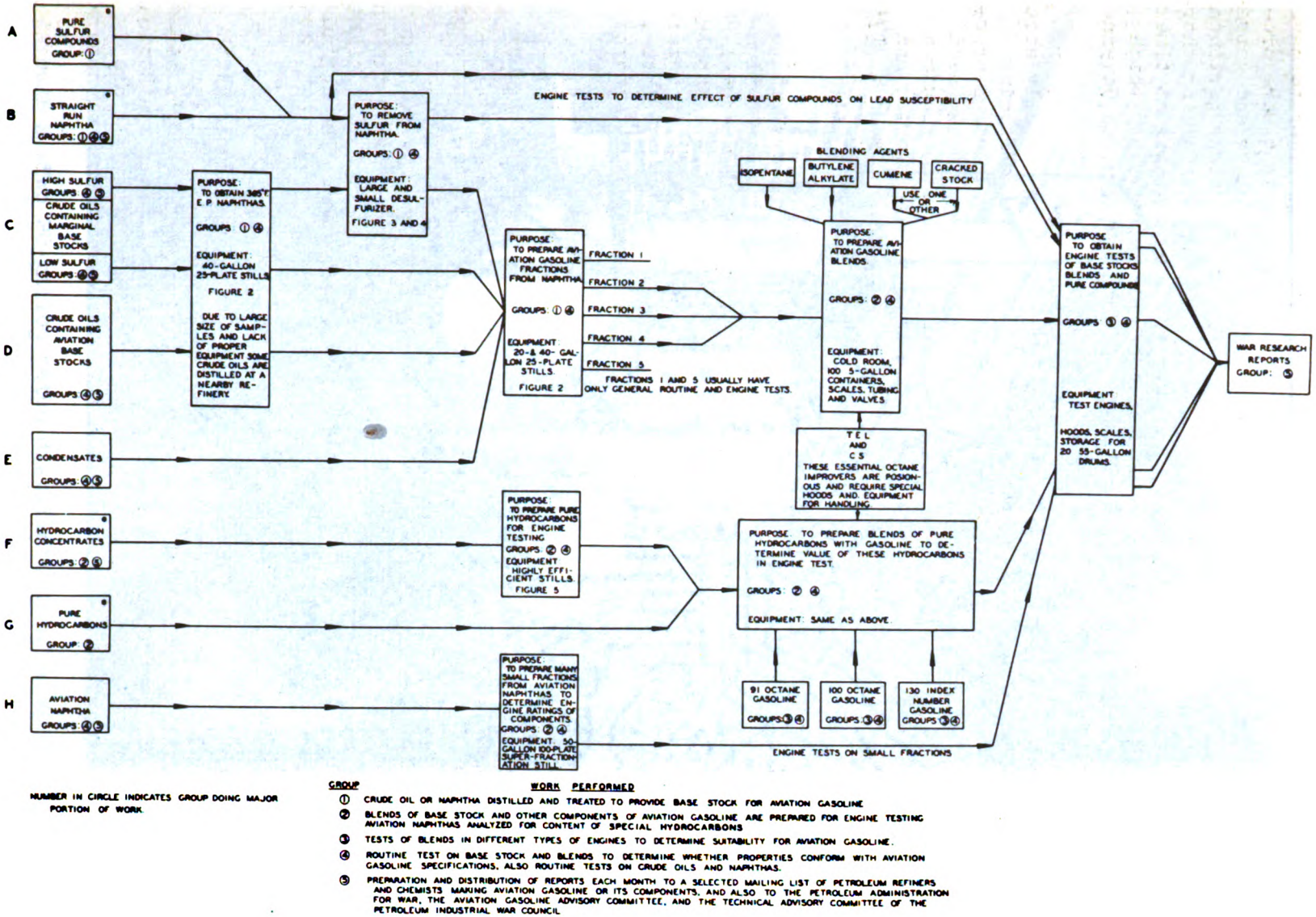
A
PURE SULFUR COMPOUNDS GROUP: ①
B
STRAIGHT RUN NAPHTHA GROUPS: ①④⑤
C
HIGH SULFUR GROUPS ④⑤
CRUDE OILS CONTAINING MARGINAL BASE STOCKS
LOW SULFUR GROUPS ④⑤
D
CRUDE OILS CONTAINING AVIATION BASE STOCKS GROUPS ④⑤
E
CONDENSATES GROUPS: ④⑤
F
HYDROCARBON CONCENTRATES GROUPS: ②⑤
G
PURE HYDROCARBONS GROUP: ②
H
AVIATION NAPHTHA GROUPS: ④⑤
PURPOSE: TO OBTAIN 385°F. E.P. NAPHTHAS. GROUPS: ①④ EQUIPMENT: 40-GALLON 25-PLATE STILLS FIGURE 2 DUE TO LARGE SIZE OF SAMPLES AND LACK OF PROPER EQUIPMENT SOME CRUDE OILS ARE DISTILLED AT A NEARBY REFINERY
PURPOSE: TO REMOVE SULFUR FROM NAPHTHA. GROUPS: ① ④ EQUIPMENT: LARGE AND SMALL DESULFURIZER. FIGURE 3 AND 4
ENGINE TESTS TO DETERMINE EFFECT OF SULFUR COMPOUNDS ON LEAD SUSCEPTIBILITY
PURPOSE: TO PREPARE AVIATION GASOLINE FRACTIONS FROM NAPHTHA. GROUPS: ① ④ EQUIPMENT: 20- & 40-GALLON 25-PLATE STILLS. FIGURE 2
FRACTION 1
FRACTION 2
FRACTION 3
FRACTION 4
FRACTION 5
FRACTIONS 1 AND 5 USUALLY HAVE ONLY GENERAL ROUTINE AND ENGINE TESTS.
BLENDING AGENTS
ISOPENTANE
BUTYLENE ALKYLATE
CUMENE
CRACKED STOCK
USE ONE OR OTHER
PURPOSE: TO PREPARE AVIATION GASOLINE BLENDS. GROUPS: ② ④ EQUIPMENT: COLD ROOM, 100 5-GALLON CONTAINERS, SCALES, TUBING AND VALVES.
T E L AND C S
THESE ESSENTIAL OCTANE IMPROVERS ARE POISONOUS AND REQUIRE SPECIAL HOODS AND EQUIPMENT FOR HANDLING.
PURPOSE: TO PREPARE PURE HYDROCARBONS FOR ENGINE TESTING GROUPS: ② ④ EQUIPMENT: HIGHLY EFFICIENT STILLS. FIGURE 5
PURPOSE: TO PREPARE BLENDS OF PURE HYDROCARBONS WITH GASOLINE TO DETERMINE VALUE OF THESE HYDROCARBONS IN ENGINE TEST. GROUPS: ② ④ EQUIPMENT: SAME AS ABOVE.
91 OCTANE GASOLINE GROUPS ③④
100 OCTANE GASOLINE GROUPS ③④
130 INDEX NUMBER GASOLINE GROUPS ③④
PURPOSE: TO PREPARE MANY SMALL FRACTIONS FROM AVIATION NAPHTHAS TO DETERMINE ENGINE RATINGS OF COMPONENTS. GROUPS: ② ④ EQUIPMENT: 50-GALLON 100-PLATE SUPER-FRACTIONATION STILL
ENGINE TESTS ON SMALL FRACTIONS
PURPOSE: TO OBTAIN ENGINE TESTS OF BASE STOCKS, BLENDS AND PURE COMPOUNDS GROUPS: ③ ④ EQUIPMENT: TEST ENGINES, HOODS, SCALES, STORAGE FOR 20 55-GALLON DRUMS.
WAR RESEARCH REPORTS GROUP: ⑤
NUMBER IN CIRCLE INDICATES GROUP DOING MAJOR PORTION OF WORK.
GROUP WORK PERFORMED
① CRUDE OIL OR NAPHTHA DISTILLED AND TREATED TO PROVIDE BASE STOCK FOR AVIATION GASOLINE
② BLENDS OF BASE STOCK AND OTHER COMPONENTS OF AVIATION GASOLINE ARE PREPARED FOR ENGINE TESTING AVIATION NAPHTHAS ANALYZED FOR CONTENT OF SPECIAL HYDROCARBONS
③ TESTS OF BLENDS IN DIFFERENT TYPES OF ENGINES TO DETERMINE SUITABILITY FOR AVIATION GASOLINE.
④ ROUTINE TEST ON BASE STOCK AND BLENDS TO DETERMINE WHETHER PROPERTIES CONFORM WITH AVIATION GASOLINE SPECIFICATIONS. ALSO ROUTINE TESTS ON CRUDE OILS AND NAPHTHAS.
⑤ PREPARATION AND DISTRIBUTION OF REPORTS EACH MONTH TO A SELECTED MAILING LIST OF PETROLEUM REFINERS AND CHEMISTS MAKING AVIATION GASOLINE OR ITS COMPONENTS, AND ALSO TO THE PETROLEUM ADMINISTRATION FOR WAR, THE AVIATION GASOLINE ADVISORY COMMITTEE, AND THE TECHNICAL ADVISORY COMMITTEE OF THE PETROLEUM INDUSTRIAL WAR COUNCIL

Figure 1.-Organization chart showing the flow of samples in the evaluation of petroleum for aviation gasoline.

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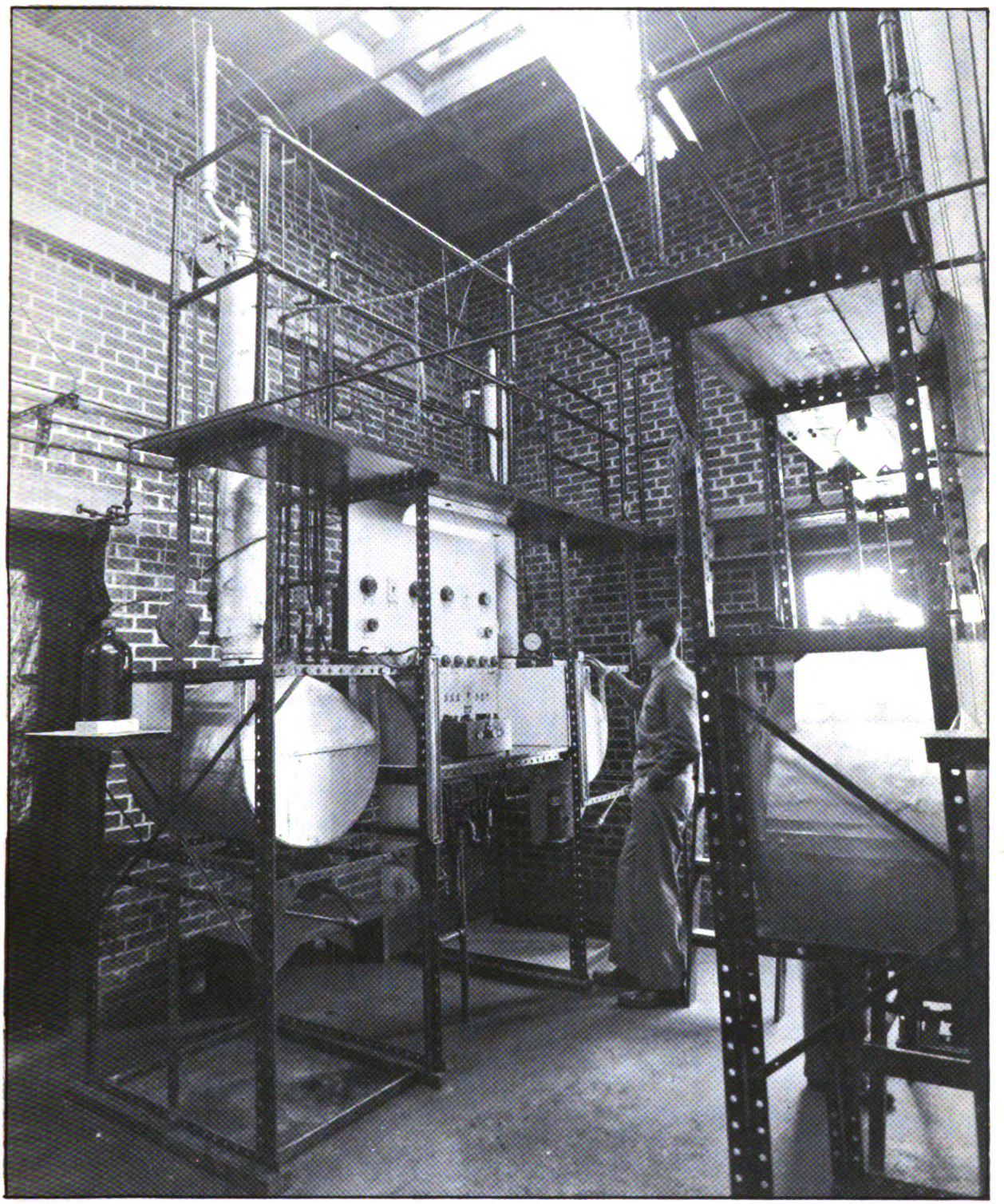

Figure 2.-Two 20-gallon batch distillation units at the Bureau of Mines Petroleum Experiment Station, Bartlesville, Okla.

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are to be blended into the final fuel. In carrying out studies designed to augment our knowledge, so that the desired increase in quantity and improvements in quality may be realized, four main projects have been studied intensively: (1) Evaluation of crude oils to determine their content of aviation base stock, (2) evaluation of base stocks in blends with high-octane agents to determine their value in a finished aviation fuel, (3) up-grading of base stocks which in their straight-run condition are not suitable for incorporation in aviation gasoline; and (4) analyses of base stocks for hydrocarbon content so that the stocks may be used to best advantage.

Evaluation of Crude Oils

The evaluation of crude oils to determine their content of base stock was a continuing project from previous years. During the fiscal year 1944, its importance has decreased primarily because most of the stocks in the continental United States were evaluated in previous years. Work during the present fiscal year, therefore, has been confined to crude oils from new fields or extensions of old fields and to reviewing some of the previous stocks that received preliminary examination. Figure 1 is a very generalized diagram of the work carried out by the Petroleum Chemistry and Refining Section. The evaluation of crude oils and condensates for base stocks is represented by blocks D and E, and some of the equipment used is shown in figure 2. Although the stills were erected to carry out work in previous years, their capacity has been doubled, and numerous improvements in their fractionating efficiency were made in the year under discussion. Of the reports issued this year, 33 contain detailed evaluations of base stocks under various conditions of testing and concentrations of tetraethyl lead.

Evaluation of Base Stocks

Probably evaluations of base stocks blended with high-octane blending agents such as alkylate, cumene, and isopentane received the most attention this year. The work required the combined efforts of all the groups involved, starting with Hempel analyses; then large-scale distillations (fig. 2); followed by preparation of blends of fractions with selected blending agents; determination of engine ratings by both the lean-mixture method, known as F-3, and the supercharge method, known as F-4; determinations of all necessary inspection properties, such as distillation range and vapor pressure; and, finally, a compilation of all these data into factual reports consisting largely of tables and graphs, with summaries emphasizing points developed concerning the applicability of the base stock to aviation fuel. As previously mentioned, 24 reports having a total of 306 legal-size pages have been issued. Comments and requests for the reports indicate that they have served a very useful purpose.

Desulfurization of Crude Oils and Base Stocks

As the supplies of petroleum have decreased, the utilization of crude oils, termed marginal because they are not of high enough quality to meet aviation gasoline requirements, has become of paramount interest. Such oils may be divided into two types - those that are marginal because of a

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high content of sulfur and those that are marginal because they contain too large a proportion of low-octane hydrocarbons. With reference to the high-sulfur oils, blocks A, B, and C in figure 1 indicate the starting point in some of the research on desulfurization. Part of the equipment used in desulfurization is shown in figure 3, and figure 4 is a detailed drawing of the pilot desulfurization unit. Most of this equipment was erected during the previous year but did not get into service until this fiscal year, and therefore numerous modifications and improvements were necessary as the research progressed.

Originally, desulfurization by means of bauxite at about 750° F. was the only method used. That method does not remove certain types of sulfur compounds, however, and as a means of eliminating those troublesome materials, one desulfurizing unit was modified to utilize a cobalt-molybdate catalyst with hydrogen at a pressure of 250 pounds per square inch. The process, originally developed by one of the oil companies, is being studied in connection with desulfurization of refractory straight-run materials in the gasoline boiling range, cracked stocks, cracking-still charging-stocks, and crude oils. Encouraging data on all of these phases have been obtained. The use of bauxite was extended also to cover crude oils and cracking-still charging stocks, with very hopeful results. Of the reports issued this year, 10 contain data showing the effectiveness of bauxite desulfurization in improving the quality of base stocks from high-sulfur crude oil. In some instances (the base stock from Slaughter crude oil, for example) it was shown that the amount of base stock that may be incorporated in a 130-grade fuel may be increased from 21 to 46 percent (an increase of over 100 percent) by the use of desulfurization.

Superfractionation of Marginal Stocks

Recently the capacity of the toluene plants in the United States has exceeded the demand for this product, and highly efficient fractionating equipment in numerous refineries has become available for other uses. One use being considered is "superfractionation." Essentially, superfractionation is the segregation of two fractions of exceptionally high-octane number from aviation naphtha. The special fractions then may be used to prepare aviation fuel of a quality better than that now commercially available. In order to carry out this process successfully, it is necessary that the refiner know which hydrocarbons are present in the naphtha and the engine ratings of those hydrocarbons or narrow boiling fractions.

Blocks F, G, and H in figure 1 indicate some of the starting points for work leading to data that enable refiners to make more intelligent use of the stocks at their disposal. The work is started with high-efficiency laboratory distillations in small-scale equipment such as that shown in figure 5. However, since the ultimate objective is knowledge of the octane numbers of the various fractions, larger equipment was necessary. A column having a theoretical plate efficiency of 80 to 100, with a stillpot capacity of 50 gallons was erected for the purpose and is now in operation. That unit permits the preparation of very narrow-boiling range fractions

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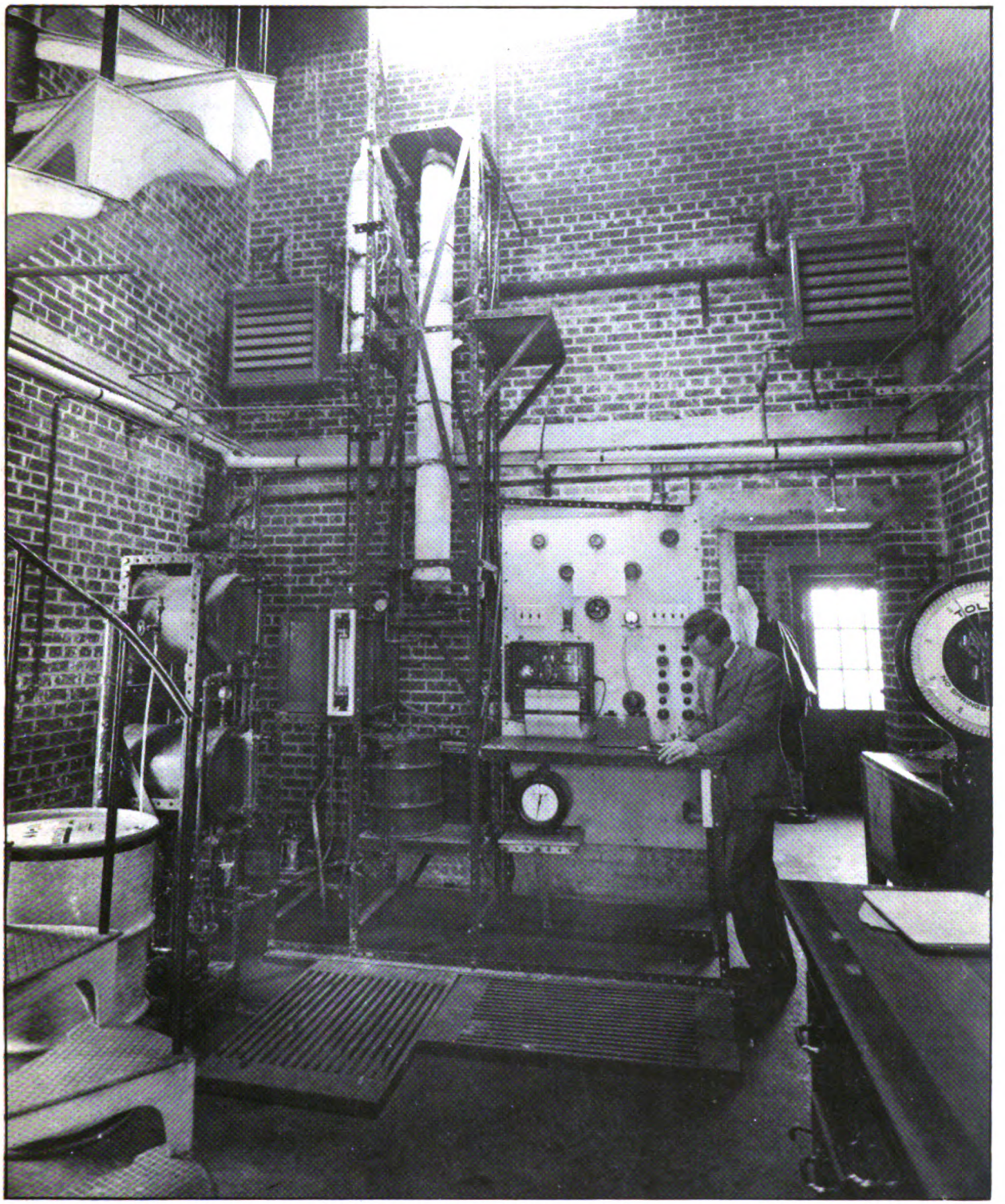

Figure 3.-Pilot-plant desulfurization unit of the Bureau of Mines Petroleum Experiment Station, Bartlesville, Okla.

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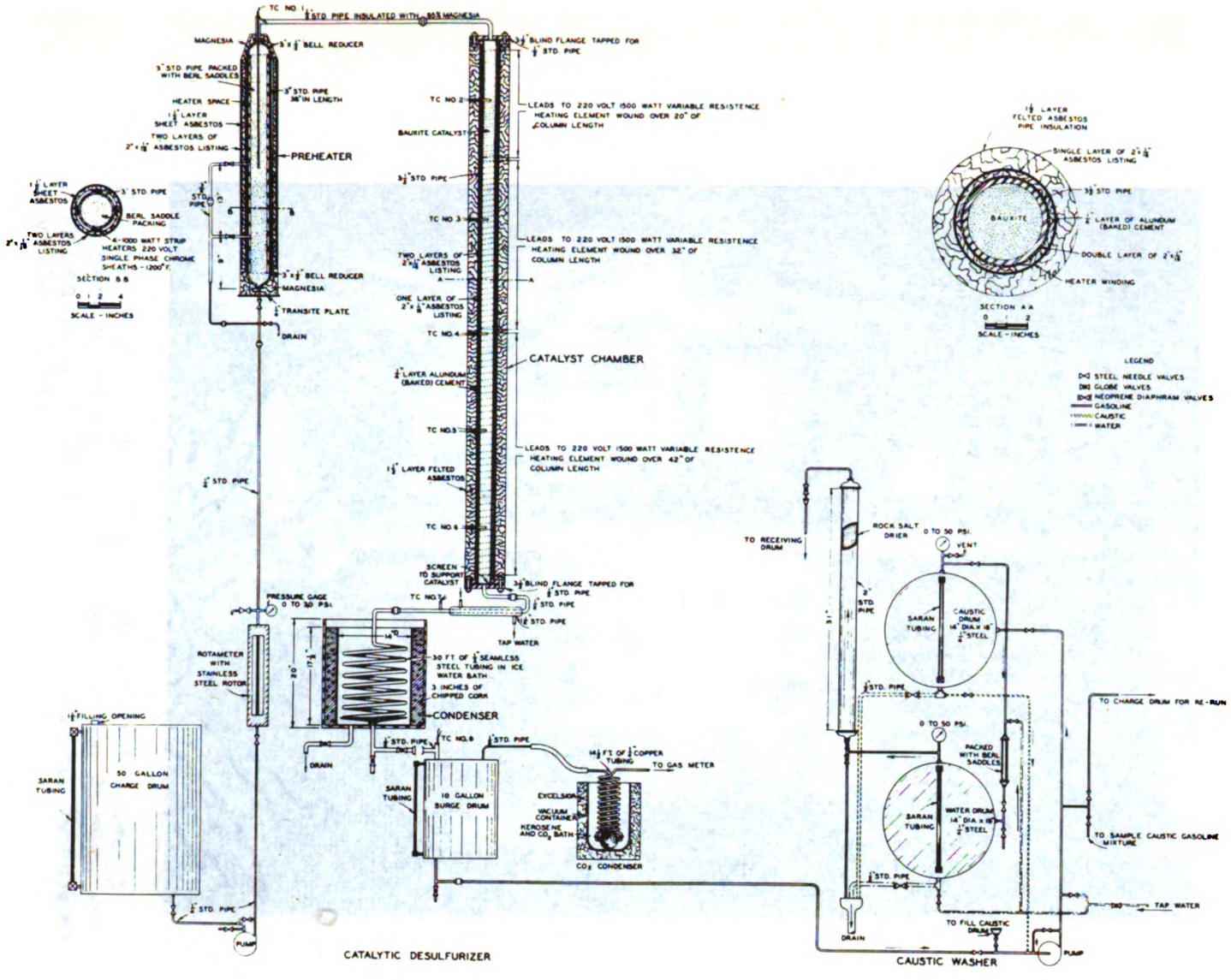

Figure 4.-Detail drawing of pilot desulfurization unit shown in figure 3.

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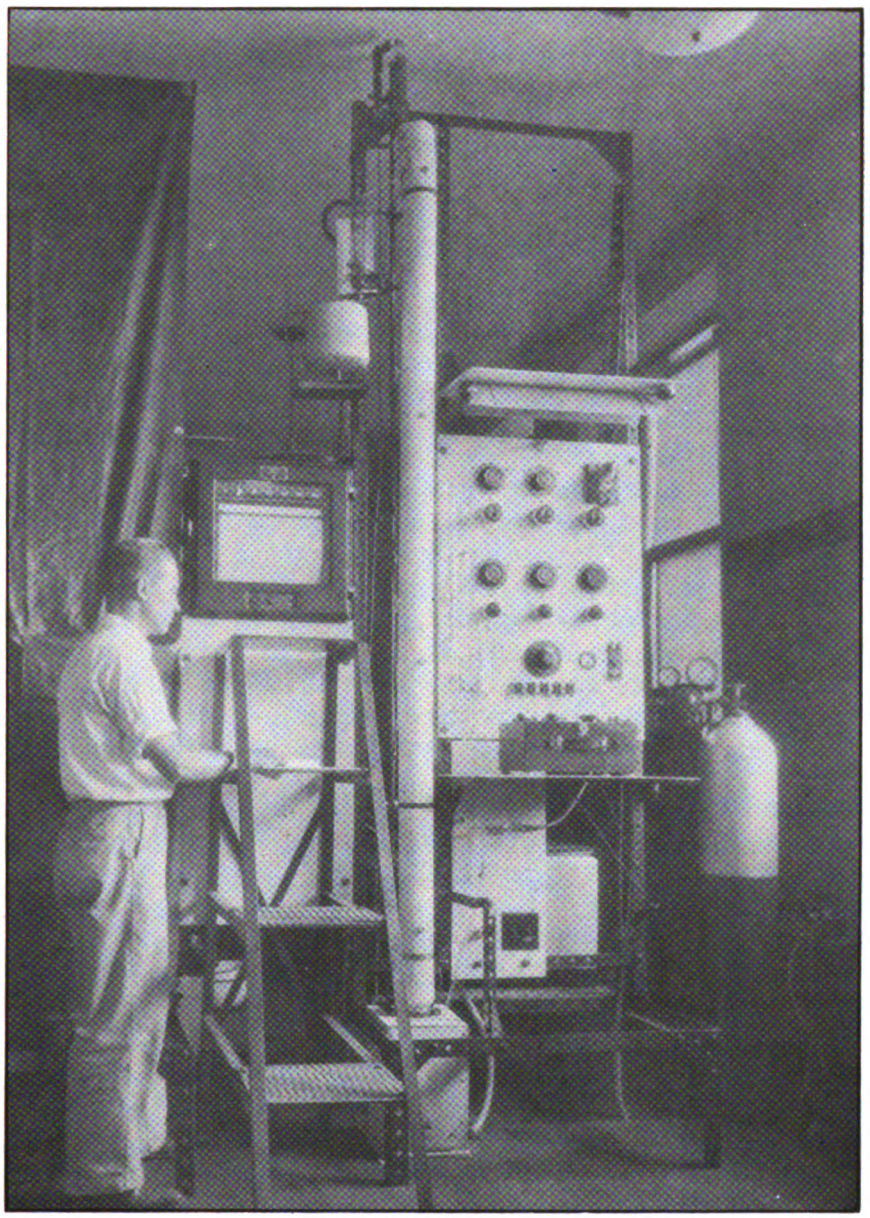

Figure 5.-80-plate distillation unit used in superfractionation studies of the Bureau of Mines Petroleum Experiment Station, Bartlesville, Okla.

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large enough so that engine ratings may be determined throughout the boiling range of the naphtha charging stock. Supplementing this, most of the naphthas studied during the past year were analyzed by methods developed at the Division's experiment stations, and 18 of the reports issued during the year carry complete graphical analyses of the hydrocarbon content of the naphthas through the boiling range 100° to 320° F. As soon as enough accurate values for engine ratings of pure hydrocarbons are available, it should be possible to calculate from these values the probable engine rating of any boiling-range fraction that is desired.

Sulfur Compounds and Special Hydrocarbons

To aid in supplying needed information on fuel characteristics of hydrocarbons and on the effect of sulfur compounds in fuels, work was initiated to separate and purify several special compounds. Approximately 7 gallons of 2-methylpentane of 95 to 96 percent purity were fractionated from a commercial "isohexan," and engine tests will be made to ascertain its knock characteristics. A smaller amount of 3-methylpentane was fractionated from the same commercial stock, and additional quantities are being separated and purified. Recent experiments showed the best source for 1,2 dimethylcyclopentane and 1,3 dimethylcyclopentane to be the isomerization of methylcyclohexane with anhydrous aluminum chloride as a catalyst. Yields of 40 percent or more on a single reaction were obtained in trial experiments. The synthetic method appears more feasible than separation by fractionation from petroleum stocks, because these stocks usually contain only small quantities of naphthenes mixed with paraffins of very nearly the same boiling points. Separation by distillation is almost impossible.

In addition to the preparation of individual hydrocarbons for engine testing, small quantities of the hydrocarbons will be processed further to the highest purity attainable, and their chemical and physical properties will be determined. One of the results of this work will be that the accuracy of methods for hydrocarbon analysis will be enhanced by the availability of better values for the physical properties of the individual hydrocarbons.

Sulfur compounds are purified when available from commercial sources, and others are synthesized. Thiophene is purified by chemical treatment and fractionation. Cyclic sulfides such as trimethylene, tetramethylene, and pentamethylene sulfides are prepared by synthesis. The quantities of sulfur compounds required for engine tests are not as great as those required for hydrocarbons, because only small amounts are used in blends. Known quantities of sulfur compounds also will be added to desulfurized naphthas in experiments to test the effectiveness of commercial desulfurization processes. Small quantities of sulfur compounds will be purified further for chemical and physical property determinations.

Development of Methods of Hydrocarbon Analysis

Hydrocarbon analyses already have been touched upon. The laboratories at both Bartlesville and Laramie contributed to the work of the A.S.T.M.

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Committee D-2, Subcommittee XXV on hydrocarbon analyses, and in addition prepared four special reports describing analytical methods developed in the Bureau's laboratories. One of the methods is a rapid quantitative method for determining toluene and other hydrocarbons that may be converted to toluene by appropriate refinery processing. In addition to the 18 hydrocarbon-analyses graphs previously mentioned, 19 samples were analyzed for their natural and potential toluene content. The subject of hydrocarbon analysis is being studied intensively throughout the country, and although present methods in use by the Bureau probably are as advanced as those in most laboratories, they are not entirely satisfactory. The development of new analytical methods is important, and studies making use of absorption spectra of ultraviolet and infrared light have been initiated. Ultraviolet equipment is in use at both laboratories.

ANALYSIS OF CRUDE OILS

The greater need and demand for Hempel analyses of crude oil occasioned by the advent of war has continued, and this year the general laboratory made 174 complete Hempel analyses on crude-oil samples. The crude oils were from fields distributed among the States as follows: Oklahoma, 56; Texas, 44; Kansas, 19; Illinois, 11; Michigan, 9; Louisiana, 8; California, 7; Mississippi, 6; New Mexico, 6; Ohio, 5; West Virginia, 1; Kentucky, 1; Florida, 1. Many of these samples were from new fields, and the information obtained from the Hempel analyses furnished the first indication as to their suitability for manufacture of aviation gasoline.

Because of the importance of West Texas fields, the Bureau published all the available crude-oil analyses for this region in a Report of Investigations released in January 1944.4/

SURVEY OF MOTOR GASOLINE

Semiannual surveys of motor gasoline have been made since 1936 in cooperation with the Coordinating Fuel Research Committee, but they were discontinued in February 1942 because the Committee felt that publication of such data might provide information useful to the enemy. The problem was resumed in May 1943, and tabulation of data for the winter 1942-43 was completed. That report was issued in June 1943.5/ The report for the summer of 1943 was prepared and released in December 1943,6/ and the report for the winter 1943-44 was released in May 1944.7/

4/ Guthrie, Boyd, Analyses of Crude Oils from Some West Texas Fields: Bureau of Mines Report of Investigations 3744, 1944, 45 pp.

5/ Kraemer, A. J., and Blade, O. C., Cooperative Fuel-Research Motor-Gasoline Survey, Winter 1942-1943: Bureau of Mines R.I. 3716, 1943, 28 pp.

6/ Kraemer, A. J., and Blade, O. C., National Motor-Gasoline Survey, Summer 1943: Bureau of Mines R.I. 3735, 1943, 28 pp.

7/ Blade, O. C., National Motor-Gasoline Survey, Winter 1943-1944: Bureau of Mines R. I. 3758, 1944, 28 pp.

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THERMODYNAMIC RESEARCH ON HYDROCARBONS

Several years ago the American Petroleum Institute initiated a program to determine the physical properties of hydrocarbons found in the lubricating-oil range of petroleum. At the request of those directly responsible for the conduct of this project, the heats of combustion of 10 of the hydrocarbons submitted by the American Petroleum Institute were determined by the Petroleum and Natural Gas Division. The results of the investigation have been compiled and submitted for publication in the Journal of the American Chemical Society.

An experimental determination of the heat capacity of hexamethyl ethane, a chemical compound in which there is wide interest because of its relation to other hydrocarbons having high-octane ratings, and also because of its potential use as a cryoscopic liquid, has been made over the temperature range 55° K. to 383° K. (-218° to -110° C.). During this investigation a careful study was made of the behavior of the compound in the neighborhood of its melting point to establish the existence or nonexistence of a second crystalline form. This knowledge is of paramount importance in analytical procedure for determining purity. The results indicated that there was not a second form. This investigation was undertaken in collaboration with the Ethyl Corporation. The specific-heat measurement will be extended to 12° or 13° K. when liquid hydrogen becomes available.

ANILINE FUNCTION OF HYDROCARBONS

Aniline points of hydrocarbons and hydrocarbon mixtures are useful tools for hydrocarbon analysis and for estimation of characteristics of petroleum products such as Diesel fuels, lubricants, and others. A report8/ giving an extensive survey of the literature on aniline points has been published, and a new relationship, "aniline function," is described therein. The "aniline function" is a correlation of critical solution temperature with molecular weight and can be used in the selection of data and detection of errors in published and determined values, or in calculating boiling points of compounds whose boiling points cannot be experimentally determined but whose critical temperature can be. The function also may prove valuable in the study of molecular structure.

8/ Ball, John S., Aniline Points of Hydrocarbons: Bureau of Mines Report of Investigations 3721, 1943, 49 pp. Reprinted in Nat. Pet. News, sec. 2, vol. 36, No. 18, May 3, 1944, p. R-297.

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PRIMARY EXTRACTION OF OIL AND GAS

ENGINEERING STUDIES OF OIL AND GAS FIELDS

Reports of Investigations 9/ 10/ 11/ were published in the fiscal year 1944 on three fields in the Southwest that were studied in the previous year. These reports concluded peacetime assignments of the Division, and all other engineering studies of oil and gas fields in the United States were at the direction of agencies charged with the responsibility of supplying petroleum and petroleum products for the armed forces. The information obtained in the war assignments has been mimeographed, and copies have been distributed to the proper war agencies and operating companies that collaborated in their preparation. It is hoped that most of the information contained in the wartime reports can be published and distributed in the future, but for the time being it must be considered restricted.

Published Nonrestricted Reports

Mexia-Powell Fault-Line Fields of Texas

In a study of a group of five fields in the Mexia-Powell fault line, the sandtone formations and conditions that controlled the accumulation of oil and gas in the reservoirs received special attention. Because the fields are nearly depleted, many factors that usually are assumed or estimated can be obtained from records of actual performance. Although numerous oil and gas fields in the United States were discovered before the Mexia-Powell fault-line fields, few of them have reached the stage of depletion by primary methods attained by this group; hence, a detailed study of the five fields offers a standard of experience by which other similar fields may be measured.

Rodessa Field, Louisiana, Texas, and Arkansas

The report on the Rodessa Field of Texas and Louisiana presents a complete exposition of underground conditions and analyses of modern methods of development in a field where oil and gas accumulated on the upper side of a major fault in both sandstone and limestone formations.

9/ Hill, H. B., and Guthrie, R. K., Analysis of Oil Production in the Near-Depleted Mexia-Powell Fault-Line Fields of Texas: Bureau of Mines Report of Investigations 3712, 1943, 83 pp.

10/ Hill, H. B., and Guthrie, R. K., Engineering Study of the Rodessa Oil Field in Louisiana, Texas, and Arkansas: Bureau of Mines Report of Investigations 3715, 1943, 126 pp.

11/ Carpenter, Charles B., and Schroeder, H. J., Magnolia Oil Field, Columbia County, Ark. Part I, Petroleum-Engineering Study (Alton B. Cook); Part II, Derivation and Application of Material-Balance Equations: Bureau of Mines Report of Investigations 3720, 1943, 115 pp.

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Magnolia Field, Arkansas

The petroleum-engineering report on the Magnolia Field in Arkansas gives a detailed analysis of the reservoir conditions and development practices in the largest oil and gas reservoir that has been found in the Smackover limestone. Oil and gas have been found in the Smackover limestone in 15 other fields in Arkansas, and an intensive search is being made for similar accumulations in this formation in Texas and Louisiana. The benefits accruing from uniform withdrawal of oil and gas over a prolonged period were stressed; and the serious corrosion menace to metal equipment caused by hydrogen-sulfide gas commonly found in the Smackover limestone was emphasized in this report for the guidance of operators in other fields that produce under similar hydrogen sulfide conditions.

Restricted Reports

Elk Basin Field, Wyoming and Montana

The largest reserve of petroleum to be developed in the United States in 1943 - reliably reported as 300 million barrels - is in the Tensleep formation, Elk Basin oil field, Wyoming and Montana. That reserve must be husbanded carefully so that it may be made available in the greatest quantity possible without jeapordizing the future of the field for commercial oil recovery. Extensive field and laboratory studies were made of the oil and gas in the Tensleep sand reservoir and the reservoir itself and to determine the ability of the wells to produce oil. Data from these studies were reported to the Petroleum Administration for War and six operating companies to serve as a guide and basis for determining a suitable operating program for the field.

The investigations indicated (1) pressures to which the reservoir may be lowered before detrimental effects to the reservoir oil will begin taking place because of the release of gas from solution, (2) the amount of gas that should be produced with each barrel of oil, (3) the amount of shrinkage to be expected when the reservoir oil is produced as marketable oil, and (4) the concentrations of the damaging and dangerous hydrogen sulfide gas that is in solution in the oil and must be produced with it. Study of the changes in reservoir pressure as oil was withdrawn determined the rate at which oil can be taken from the reservoir if the natural energy of encroaching edgewater is to be utilized for producing the oil, and the need for supplementing this energy if withdrawal rates are increased.

North McCallum Field, Colorado

An oil distillate with large quantities of CO_2 gas is produced from the North McCallum Field near Walden, Colo. This distillate was found to be unusually well suited as a Diesel fuel for certain requirements of the Navy. Consequently, active development of the field was started, and plans for a plant to process the well fluids to recover the distillate were formulated. Although fluids from one well had been analyzed previously, fluids from a second well were sampled and analyzed to provide additional information.

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Data on well and reservoir characteristics were ascertained. A report was prepared for the operating company and the Geological Survey to provide data which will permit an accurate evaluation of the reservoir fluid.

Cut Bank Field, Montana

There are about 75 square miles of oil-productive area in the Cut Bank, Montana, oil field. Some parts of the field are still being developed, whereas others are almost depleted. A report to the Petroleum Administration for War and eleven operators was prepared giving data on the characteristics of the fluids in the reservoir and of the reservoir itself. The data are necessary for proper evaluation of this field in conjunction with a program to increase the recovery of oil. Such programs are becoming increasingly important owing to the inability to locate new resources of oil commensurate with the rate at which the present reserves are being depleted.

West Cement Field, Oklahoma

The report, No. 2-A, on the West Cement Gas Field, Caddo County, Okla., is the third report resulting from continuation of a general study of that field. Previously, two reports were made in the fiscal year 1943. Report 2-A, containing 12 pages of text, 2 tables, and 7 illustrations, contains a study of reservoir pressure stabilization when all the wells in the Medrano gas cap were shut in for a period of two weeks, and a study of interference between wells when some of the wells were opened to produce whereas others remained shut-in. The purpose of the study was to explain wide variations of pressure in areas of the field and to determine the degree to which the areas may be interconnected by porosity.

Sejita Field, Texas

The engineering study and estimation of reserves, Sejita Field, Duvall County, Texas, includes (1) discussions of the engineering and geological features of the field, illustrated with cross-section, contour, and isopachous maps, and (2) estimates of the oil and gas reserves in the first, second, and third Hockley sandstone reservoirs.

The report submitted to the Petroleum Administration for War and interested operators of wells in the field contains 34 pages of text, 22 illustrations, and 3 tables.

Carthage Field, Texas

A report was prepared in two parts to correlate and disseminate knowledge gained from investigations in the Carthage Field, Panola County, Texas. Part I is an engineering study and estimation of reserves in the field and includes (1) a discussion of the engineering and geological features of the field illustrated with cross-section, contour, and isopachous maps, (2) an estimate of the gas and condensate reserves in the Hill, Upper Pettit, and Lower Pettit zones, and (3) a discussion of the

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physical characteristics of the Hill, Upper Pettit, and Lower Pettit reservoirs with respect to the production of wells in the field and the feasibility of carrying on cycling operations. It consists of 56 pages of text, 31 illustrations, and 20 tables.

Part II of the report contains information on fluid characteristics in the field and includes discussions of (1) the selection of wells for obtaining representative samples of fluid from the Upper and Lower Pettit zones, (2) the physical characteristics of the wells and reservoirs, with tables and illustrations, (3) complete hydrocarbon analyses of both gas and liquid from the Upper and Lower Pettit zones and the combined analyses of the reservoir fluid, (4) relationship of hydrocarbon fluid accumulation versus pressure and temperature on the reservoir, and (5) dewpoint properties of the reservoir fluid at reservoir temperature and other temperatures. This part of the report consists of 34 pages of text, 12 pages of appendix, 21 illustrations, and 18 tables.

Copies of parts I and II were made available to the Petroleum Administration for War and companies operating in the field.

Chapel Hill Field, Texas

To supplement the engineering report prepared in the preceding fiscal year on the Chapel Hill Field, Smith County, Texas, flow characteristics and properties of the fluid produced from the Paluxy formation in the field were investigated. The results of the investigations were printed as part II of the Chapel Hill report and distributed to the Petroleum Administration for War and operators in the field. Consisting of 42 pages, 11 illustrations, and 7 tables part II contains discussions of (1) the selection of wells for obtaining representative samples of fluid from the formation, (2) physical characteristics of the well and reservoir, illustrated with tables and illustrations, (3) complete hydrocarbon anaylses of both gas and liquid from the Plauxy reservoir and the combined analyses, (4) relationship of hydrocarbon fluid accumulation versus pressure and temperature, and (5) dewpoint properties of the reservoir fluid at reservoir and other temperatures.

Katy Gas-Condensate Field, Texas

The engineering study and estimation of reserves, Katy Field, Waller, Harris, and Fort Bend Counties, Texas, includes (1) a discussion of the engineering and geological features of the field, illustrated with cross-section, contour, and isopachous maps, and (2) estimates of the gas reservos in zones, I, II, III, IV, and V.

The report submitted to the Petroleum Administration for War and companies in the field consists of 74 pages, 35 illustrations, and 24 tables.

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Old Ocean Field, Texas

The engineering study and estimation of reserves, Old Ocean Field, Brazoria and Matagorda Counties, Texas, includes (1) a discussion of the engineering and geological features of the field, illustrated with cross-section, contour, and isopachous maps, and (2) estimates of the oil and gas reserves in the B.R.L.D., Chenault, Armstrong, Campbell, and Larsen zones.

The report submitted to the Petroleum Administration for War and operators in the field consists of 106 pages, and appendix, 20 illustrations, and 24 tables.

Lake Creek Field, Texas

An investigation of the engineering, geology, and reserves of the eight productive zones of the Wilcox formation, Lake Creek Field, Montgomery County, Texas, was partly complete at the end of the fiscal year.

Seeligson Field, Texas

A study of the Seeligson Field, Jim Wells County, Texas, is being undertaken to determine the advisability of cycling gas in the field. The investigations will include estimation of oil and gas reserves in the field.

WELL-SPACING STUDIES

The proper spacing of wells continues to be a problem of importance to the petroleum industry, not only from an engineering standpoint, which, among other things, involves the ultimate recovery of oil, but also from an economic point of view. During the year, correlation of the effect of well density upon the ultimate recovery of oils of different A.P.I. gravities (reduced to reservoir conditions) was augmented by data on a number of additional fields. In all, 112 fields in 13 States have been analyzed. Charts exhibiting the relationship between oil recovery and spacing in sand fields in which the oil is underlain by mobile water include data on 64 fields in 10 States; 31 fields in 7 States furnish data used in compiling the charts showing the recovery-spacing relations in limestone fields; and data on 17 gas-expansion type reservoirs in 6 States were used in compiling the third set of charts. As pointed out in last year's report, charts for sand reservoirs with natural water drive indicate that the percentage increase of ultimate recovery as a result of closer spacing of wells is greater for heavy than for light gravity oils.

The results of the well-spacing studies were presented to the Committee on Well-Spacing and Allocation of Production, American Petroleum Institute, in a meeting in Chicago, November 8, 1943. It was the expressed opinion of the committee that the charts and description of the relationship between recovery and well-spacing embodied a very important presentation and justified a close study and additional work along this line by all members.

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DRILLING-FLUID RESEARCH

Continuing the drilling fluid research program initiated several years ago by engineers of the San Francisco office, interest has been directed chiefly toward studies of oil-base drilling fluids. Close contact was maintained with private investigators of the problem, and considerable research help has been exchanged.

Recently there has been an increasingly wider recognition of the advantages of using oil-base muds for "drilling-in" operations. Poor-quality, water-base, drilling-mud fluids permit the infiltration of water into the small pores of the oil-bearing formation, and a thick mud sheath is deposited on the walls of the hole. Thus, the flow of oil into the well is retarded. Moreover, many wells are being drilled in semidepleted areas that are particularly susceptible to infiltration of water from water-base drilling fluids. Laboratory tests show that satisfactory drilling fluids may be made with oils produced in many of these fields by the addition of small quantities of suitable chemicals. It is significant, however, that one of the new types of oil-base drilling admixtures now used in California is not satisfactory if mixed with some Mid-Continent and Eastern oils.

Because of the importance of reliable core data for use in operating oil fields efficiently and estimating crude-oil reserves, attention also is being directed to the development of improved types of oil-base drilling fluids for use in recovering cores that have been subjected to a minimum amount of flushing. Accurate determinations of oil, water, and gas contents of an oil-bearing formation cannot be obtained if the pore spaces of the core have been washed with drilling fluid.

New methods for mixing and controlling the properties of oil-base drilling fluids that permit very low fluid losses to porous cores have been developed in the laboratory. Data have been obtained that indicate that the pH of oil-base drilling fluids can be measured and used to control many of the properties of the fluid during core operations. In a coring test made in Texas with the A.P.I.-Bureau of Mines core barrel, the pH measurement was found to be a very important factor in controlling the properties of the drilling fluid to obtain the best cores.

Because the use of oil-base drilling fluids is relatively new, very few complete data are available for comparison to show the effect of the fluids on the productivity of wells. Bureau of Mines engineers, however, are gathering all information available regarding the use of these fluids in drilling operations. The attention this new development is receiving by the Bureau engineers and other investigators undoubtedly will yield valuable results.

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SECONDARY RECOVERY OF OIL

METHODS OF INCREASING THE RECOVERY OF OIL IN THE MID-CONTINENT AREA

The importance of increasing the recovery of oil from known reserves became more evident during the year when for the first time the productive capacity of the oil fields of the country was extended to meet the demand. According to W. V. Howard,12/ new reserves in 1944 were less than production of crude petroleum for that year; the ratio of estimated known reserves to the annual rate of production declined from 15 to 13.5.

Seven secondary-recovery projects in the Mid-Continent area were studied during the year. These were surveys of water-flooding projects in Oklahoma, Kansas, and Illinois, an investigation of water-flooding in limestone reservoirs, a study of water-injection in the Clay City Field in Illinois, a study of air- and gas-injection in Illinois, and an investigation of the manufacture and use of cement-lined pipe in water-flooding operations.

History of Water-Flooding in Oklahoma

The first of the projects was concluded with the publication of Report of Investigations 3728,13/ which gives in detail the results on 73 water-flood projects in Oklahoma. As of July 1, 1942, a total of 8,157 acres of oil-sand on approximately 350 leases had been flooded and 15,495,937 barrels of crude petroleum had been recovered since the beginning of water-flooding operations. A typical water-treating installation for a water-flooding project is shown in figure 6.

History of Water-Flooding in Kansas

The second project, a survey of water-flooding in Kansas, was completed and the manuscript was forwarded to Washington for publication as a Report of Investigations,14/ The report shows that more than 4 million barrels of petroleum were recovered as a result of injection of 40 million barrels of water on 110 leases comprising approximately 2,600 acres.

Water-Flooding in Illinois

A third survey, water-flooding of oil sands in Illinois, has been completed, and a manuscript giving the results of the investigation is being criticized by members of the Bureau.

12/ Howard, W. V., Proven Reserves: Oil and Gas Journal, vol. 42, No. 38, Jan. 27, 1944, pp. 116-117.

13/ Taliaferro, D. B., and Logan, David M., History of Water Flooding of Oil Sands in Oklahoma: Bureau of Mines Rept. of Investigations 3728, 1943, 182 pp.

14/ Grandone, Peter, History of Water Flooding of Oil Sands in Kansas: Bureau of Mines Rept. of Investigations 3761, 1944, 146 pp.

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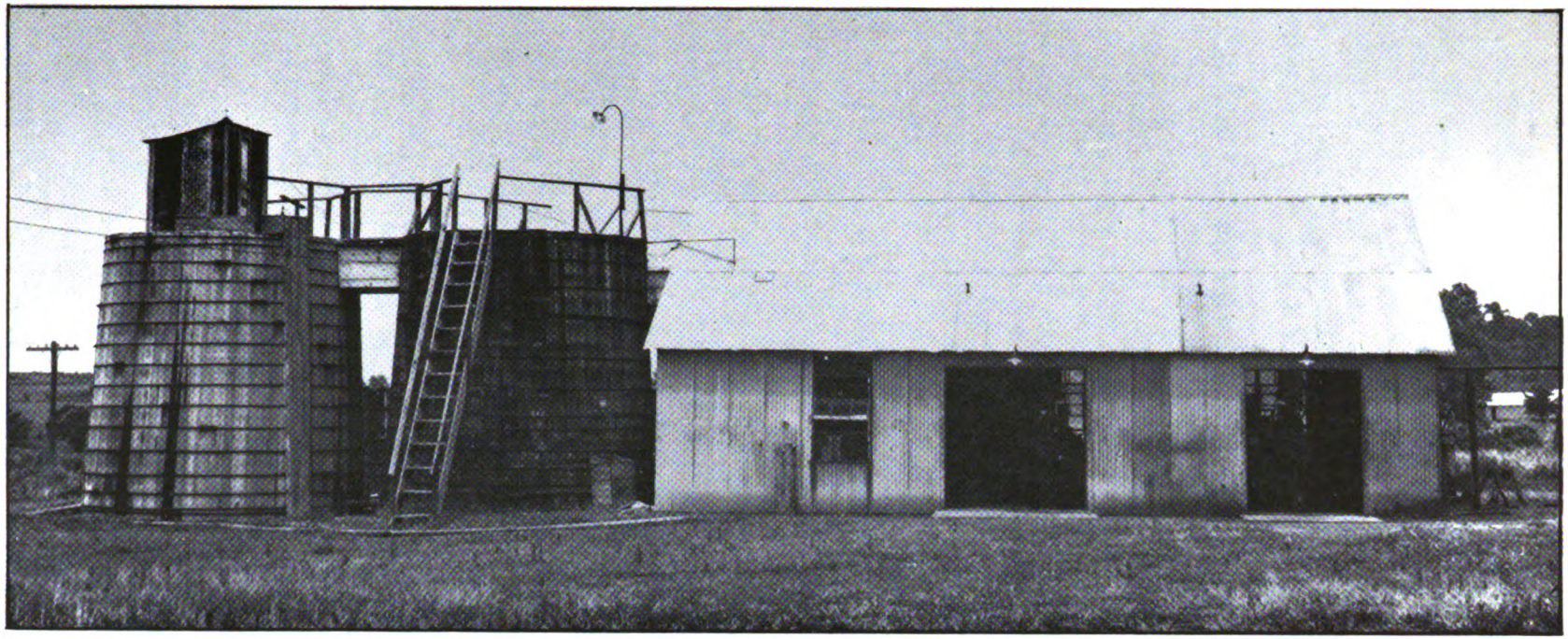

Figure 6.-Typical water-treating plant for water-flooding project in eastern Oklahoma.

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Air and Gas Injection in Illinois

A study was made of four air- and gas-injection projects in stripper fields in Illinois, and a report giving the results of this study is being prepared. Many of the wells in the older fields of Illinois are being abandoned, but the results of the study show that a large percentage of these wells might be operated at a profit for several more years by air- and gas-injection methods.

Secondary Recovery Methods in Limestone Reservoirs

The application of secondary recovery methods in limestone reservoirs presents problems not usually encountered in their application in sandstone reservoirs. For this reason only a few attempts at water-flooding or gas-injection have been made in limestone reservoirs. Bureau engineers have begun collecting data on the projects that have been initiated to date in reservoirs of this type. Of the projects, water-injection in the Clay City Field, Illinois, has given such exceptional results that work is being started on a manuscript describing this operation and giving the results that have been obtained.

Typical of the reception given reports pertaining to secondary recovery is the following resolution adopted by the Interstate Oil Compact Commission at its quarterly meeting in Wichita, Kans., on December 11, 1943:

> A survey by the United States Bureau of Mines cooperating with the state of Oklahoma, entitled "History of Water Flooding of Oil Sands In Oklahoma" [R.I. 3428] by D. B. Taliaferro and D. H. Logan, presented at this meeting by Ludwig Schmidt, Senior Petroleum Engineer, Bureau of Mines, Bartlesville, Oklahoma, is now available to the public.
>
> This comprehensive report is a review of water-flooding operations in the State of Oklahoma and contains detailed information regarding all such projects in the State.
>
> The Interstate Oil Compact Commission commends this fine report as a valuable contribution to the progress of secondary recovery operations, and recommends that this type of cooperation by the Bureau of Mines, the oil producing states and the industry in relation to secondary recovery be continued.

Respectfully submitted by

THE RESOLUTIONS COMMITTEE

By J. C. Harter
Chairman

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Brine-disposal Systems

The use of brines as the propulsive medium in water-flooding operations is gaining favor with many operators. However, handling brines produced in conjunction with crude petroleum and natural gas presents many technical problems and difficulties. To obtain information regarding the best practices for handling deep-seated brines, the subsurface brine-disposal systems in Western Kansas were surveyed in 1942-1943, and the results were published as a Report of Investigations.15/

Reclaiming Pipe by Cement Lining

One of the major problems of most operators of water-flooding projects is the corrosion of pipe by the water that must be handled. This difficulty has been overcome in many areas by using pipe containing a cement lining. Incidentally, new pipe is not required in many installations, such as surface lines; thus, a great deal of thin-wall used pipe has been reclaimed and cement-lined with resulting substantial saving in material that otherwise would be "junked." The value of this process is evidenced by the fact that in 1940 only one plant was cement-lining pipe in Oklahoma and none in Kansas, whereas today there are three plants in Oklahoma and one in Kansas. A study has been made of the manufacture and uses of cement-lined pipe, and a manuscript is being prepared that gives the results of the investigation.

METHODS OF INCREASING THE RECOVERY OF OIL IN THE APPALACHIAN REGION

The work on methods of increasing oil production in the Appalachian region includes studies of (1) oil-well reconditioning, (2) horizontal drilling of oil sands from a vertical shaft, (3) correlation of the efficiency of air- and gas-drive secondary oil recovery with properties of the reservoir sandstones, (4) the application of siphons for flowing oil from wells on air- and gas-repressuring projects, and (5) modern engineering practice in the application of air- and gas-repressuring as a secondary recovery method. In addition, much has been done in informing operators of good engineering practice and in assisting them with individual oil-production problems.

Oil-Well Reconditioning

In the reconditioning of oil wells, different procedures are applicable depending upon the factors causing decline of production. For example, paraffin precipitation with subsequent clogging of the oil-producing sand is a relatively common condition present in wells in the Appalachian region. Operators have attempted to eliminate this condition in several different ways such as shooting with nitroglycerin, injecting steam or hot water, applying heat by introducing heat-producing chemicals, and the use of solvents. It is the purpose of the study of oil-well reconditioning to

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15/ Grandone, Peter, and Schmidt, Ludwig, Survey of Subsurface Brine- Disposal Systems in Western Kansas Oil Fields: Bureau of Mines Rept. of Investigations 3719, 1943, 20 pp.

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determine the conditions under which one of the above methods of removing paraffin is more applicable than another. Detailed data on more than 350 well-reconditioning jobs in southwestern Pennsylvania, southeastern Ohio, and West Virginia are being analyzed.

Horizontal Drilling

Approximately 2 years ago a project was started in the Franklin Heavy Field, Venango County, Pennsylvania, where a vertical shaft was sunk to the bottom of the oil-producing sand and horizontal holes were drilled into the oil sand. This procedure for producing oil is a wide departure from the standardized method of drilling vertical holes into oil sands, and because of the unusual amount of interest of the entire oil industry in this work the Bureau of Mines has had an engineer assigned to the project from its inception. A preliminary report on the development to date of the first two horizontal holes is in preparation and presents detailed information on the equipment and the method of operation.

Correlation of the Efficiency of Air- and Gas-drive Recovery with Reservoir Properties

Of the three methods of formation sampling used in Appalachian oil fields - "chip" sampling and cable-tool and rotary-diamond cores - the costs increase progressively in the order named and, in the same order, furnish more detailed information of the strata cored. Because of the higher costs of rotary cores and the dearth of practical published data on laboratory air-drive secondary-recovery tests on fresh cores, the Bureau of Mines has had only a few samples for such work. It was found, however, that the residual oil saturation, after economic air-drive, was a function of (1) porosity, (2) initial liquid saturation, (3) mean sand-grain diameter, and (4) a grain-size distribution factor. Good correlations were obtained from work on samples from one field. It is suspected that the viscosity of the oil and probably other factors also affect the general relationships. Until other satisfactory fresh samples are obtained, further work will proceed with laboratory saturated specimens. After relationships for wide ranges of conditions are definitely established, better estimates of oil recoverable by air-drive can be made from smaller core samples obtained by one of the methods less expensive to the oil operators. Core analyses have been made on a number of cable-tool cores from various fields in the Appalachian region. The study of contamination of cable-tool and rotary cores by drilling fluid was benefited by analyses of oil-sand samples obtained during excavation of the vertical shaft in the horizontal drilling project.

Application of Siphons for Flowing Oil from Wells on Air- and Gas-repressuring Projects

Field investigations are in progress on the practicability of flowing producing wells on secondary-recovery properties using air- or gas-injection. An experimental group of nine producing wells and six injection wells on a lease of one operator has been in operation for 6 months. Flow strings in

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five producing wells of two operators have been in operation for only a short time, and preliminary work is being done in installing flow strings on leases of two other operators.

Energy for flowing the wells is furnished by the produced gas and by reservoir pressure built up by injected air. Flowing is accomplished by using a flow-string design adapted from Bureau of Mines Technical Paper 460, "The Design and Operation of Gas-Well Siphons," by I. B. Williams, R. R. Brandenthaler, and Morgan Walker. Flow-string designs are made to produce periodic flows of oil and gas with no production between flows. This results in alternately applying and relieving back pressure on the sand face of the producing well.

Preliminary results indicate that wells can be made to flow at lower gas-oil ratios than were obtained when the wells were pumped at equal oil-production rates. Decreased lifting costs and more efficient use of the injected fluid are indicated by this method of production. Continued work to determine both the practicability and the range of application of flowing the oil wells in an air- or gas-injection project is in progress.

Air- and Gas-repressuring in Pennsylvania and West Virginia

Nine air-gas-drive secondary recovery projects have been analyzed from voluminous data assembled from oil, water, and gas-production records, air-gas-injection records, well records, equipment-inventory records, core analyses, and information obtained orally from the operators. The projects were selected to give a wide range of (1) geographical location, (2) producing formations, (3) manner of operation, and (4) degree of success. The fields, producing formations, and locations of the projects are as follows:

Field	Producing formations	County	State
Goodwill Hill	First Venango Third Stray Venango	Warren	Pennsylvania
Petroleum Center	Second Venango Third Venango	Venango	Do.
McDonald	Gordon Fourth Fifth	Allegheny Washington	Do.
Brenneman	Berea	Hancock	West Virginia
Union Furnace	Clinton	Hocking	Ohio
New Straitsville	Clinton	Hocking	Do.
Sistersville	Big Injun	Monroe Tyler	Do. West Virginia
Boggs	Berea	Roane	Do.
Knutters Fork	Big Injun	Roane	Do.

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Property, isopachous, and structural maps as well as curves and numerous tables were prepared. The estimated oil gained by air-gas injection in barrels per acre-foot ranged from 5 to 153. These data are in the process of further analysis and presently will be assembled in a published report.

SECONDARY-RECOVERY STUDIES IN CALIFORNIA

The rapid depletion of crude-oil reserves in California during the past few years has brought into sharp focus the need for studying the application of secondary methods in many fields of the State, particularly in the shallow fields where large volumes of heavy residual oil remain. Consideration is being given to the application of water flooding and to drifting underneath the oil-bearing formations and applying heat to the reservoirs for the purpose of reducing the viscosity of the oil to increase the rate of flow. Several small operators in the Kern River field are giving thought to mining for oil by drifting underneath outcropping sands and tapping the oil sand at depths from stations along the drifts and tunnels.

Laboratory Research on Reservoir Drainage

The equipment for this experiment consists of a wood box 3 feet square and 1 foot deep. Five wells arranged in 5-spot spacing, consisting of perforated 1/4-inch pipes, extend upward through the bottom of the box. A tunnel formed by heavy wire screen extends across the bottom of the box midway between the sides. Twenty-eight thermocouples extending inward through the sides and bottom of the box are arranged in a pattern that will indicate the distribution of heat in the reservoir when heat is applied in the tunnel. The thermocouples are connected to a potentiometer through a panel box, whereby individual readings may be taken by means of a sliding device.

A sand closely resembling that of the Kern River field was saturated with Kern River oil, after 25 percent "connate water" had been added to the pore space, and packed tightly in the box at a temperature of 84° F., the approximate reservoir temperature of the Kern River field. The box is set in a constant-temperature room maintained at 84° F. The wells are now "on production," and daily gages are being taken. After normal drainage has been completed, heat will be applied by means of a heating element placed in the tunnel. It is probable that injection of water into one of the wells will be tried.

RECOVERY OF HYDROCARBONS FROM BITUMINOUS SANDS

The drain on crude-oil reserves in California as a result of the abnormal war demand also has aroused interest in the possibility of utilizing the large surface deposits of bituminous sands in California as sources of new supply of much-needed oil. Realizing the desirability of developing a process for commercial recovery of hydrocarbons from bituminous sands, the Bureau initiated a study of the problem in 1943. Numerous runs have been made in a laboratory pilot plant in which solvents, reagents, and procedure have been varied to establish conditions best suited for a practical method of separation. Although it is too early to form definite conclusions as to

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the ultimate development of a successful commercial process, substantial progress has been made, and encouraging results have been obtained. As a technical problem, recovery of hydrocarbons from bituminous sand is entirely feasible; as a commercial problem, recovery is largely a matter of economics.

The bituminous sand being treated is from the Edna Deposit near San Luis Obispo, one of the largest in California. The bitumen contents of the samples average 11 percent by weight, or about 26 gallons per ton of material. The native bitumen in the sandstone is very viscous, having an A.P.I. gravity of 9° to 10°.

Briefly, the extraction process consists of pulping the material with gas-oil and an aqueous solution of sodium silicate in a rotary-type digester and then separating the oil in flotation cells containing weak sodium silicate solution. The percentage recovery of the bitumen from the sand and the loss of gas-oil in the sand tailings depend upon the strength of the sodium silicate solution, the mechanical agitation in working the sands, the length of time of agitation, and the temperature of the solutions. In a commercial operation it is proposed to distill the recovered oil (bitumen plus gas-oil) to recover the gas-oil and then crack the bitumen to obtain desired products.

UTILIZATION AND PROPERTIES OF ASPHALTS

Although restrictions are still in force on the manufacture and sale of asphalts for road building, greater interest in the use of asphalts for many specialties is evident. Asphalts are being used for many purposes, such as substitutes for critical metals and paints. Most camouflage paints have an asphalt base; waterproof and moisture-retaining packaging, rust-proofing, corrosion-resistant surfacing, and many other similar processes have substituted asphalt for tin, aluminum, lead, and zinc. Each of these uses requires specially prepared asphalts that meet rather rigid specifications, so that a good knowledge of the proportions, properties, and character of the constituents of the asphalts is essential to the proper manufacture of these specialized products.

Asphalt studies during the past year have been devoted largely to the development of a quantitative method of analysis for the constituents of asphalt commonly called asphaltenes, resins, and oils and the analysis of a number of asphalts by this method. The method consists essentially of separating the insoluble asphaltenes from an n-pentane solution of the asphalt by centrifuging, dispersion of the solution containing resins and oils in an alumina adsorbent, extraction of the oils with n-pentane, and a final extraction of the resins from the alumina, using benzene as the solvent. Each constituent is freed of solvent, dried, and weighed.

A number of other methods have been suggested for similar types of analyses, but it is believed that this method has several advantages over the others, principally because of the short time required for completing an analysis, the use of pure hydrocarbons as solvents with resulting ability to duplicate results, and the use of alumina rather than fuller's earth or similar clays as adsorbent.

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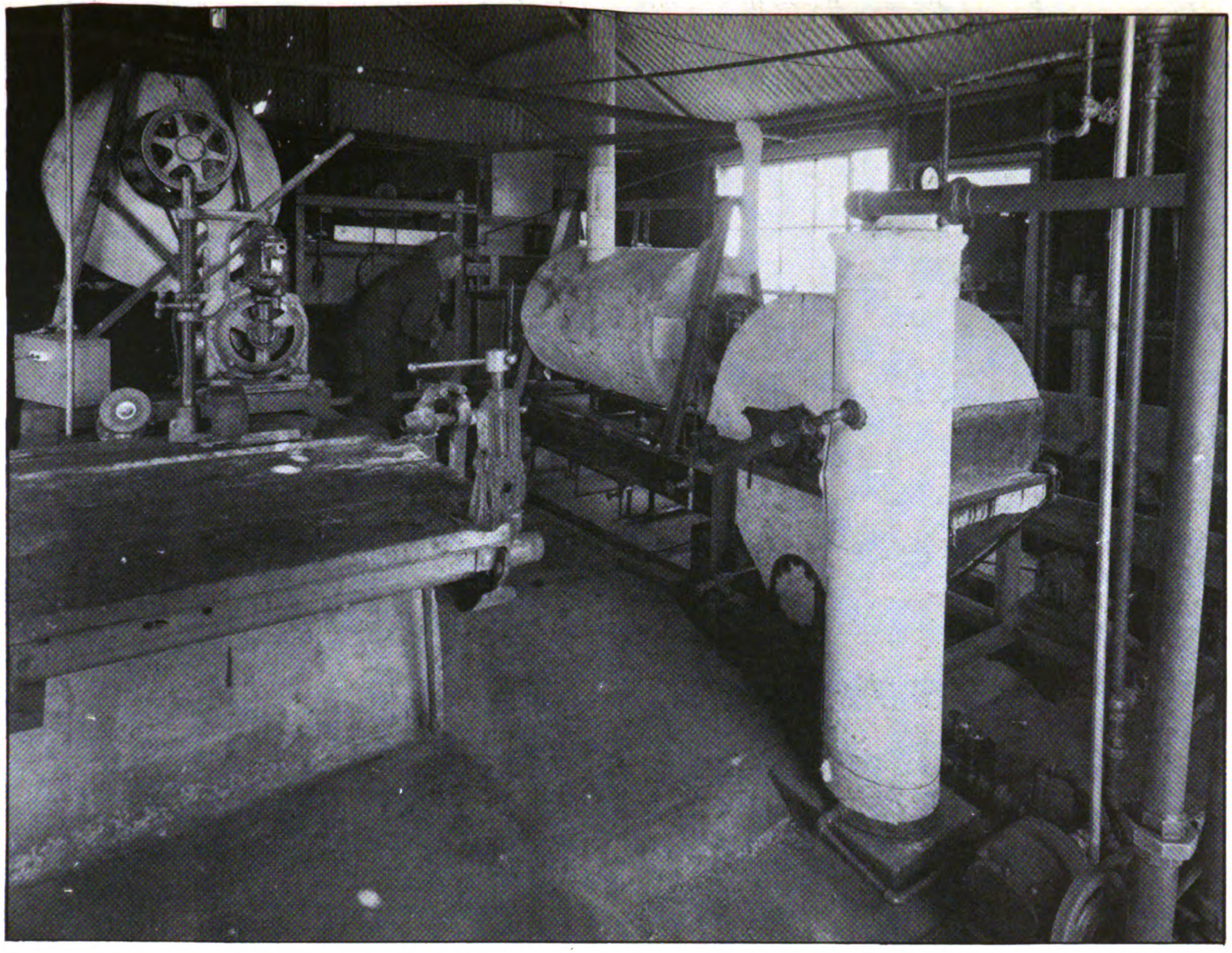

Figure 7.-Interior of processing building, pilot plant for recovery of wax from crude-petroleum waste, El Dorado, Kans.

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Approximately seventy asphalts were separated into their constituents by the above method, and the quantitative proportion of each constituent was determined. About 35 more asphalts remain to be analyzed to complete the study of Wyoming and some other asphalt-bearing crude oils.

It is contemplated that a report giving the properties of these asphalts, as determined by the common asphalt tests, and a constituent analysis of each will be written and published within the next few months.

In addition to the above work on petroleum asphalts, a number of natural bitumens and bituminous materials were analyzed and reported on to interested persons. These include 7 samples of tar-saturated sands from deposits near Vernal, Utah, an asphaltite from Ft. Washakie, Wyo., a native bitumen from Cape Simpson, Alaska, a grahamite from Stevens County, Oklahoma, and samples of the oil extracted from the Athabaska tar-sand deposits, Alberta, Canada.

RECOVERY OF WAX FROM CRUDE PETROLEUM WASTE

The economic utilization of oil-field wastes, such as tank-bottom residues, rod wax from well cleanings, and similar accumulations, continues to be a possible additional source of crude-oil cracking stock and microcrystalline wax used in the manufacture of certain war material. The work this year was directed toward the application of previous laboratory study to actual field operation of a pilot plant for the recovery of these wastes.

The pilot plant is about 3 miles west of El Dorado, Kans., and is near a large accumulation of weathered tank bottoms (200,000 barrels) containing more than 35 percent microcrystalline wax and owned by the Cities Service Co. This company and the Barnsdall Refining Co., refiners of ordnance wax, arranged to cooperate in the project.

The plant equipment was ordered early in 1943-44 and was installed as received. Installation was finally completed in April. The equipment is housed in a boiler house, processing building, pump pit and house, control laboratory, and auto-trailer office and laboratory. Two 200-barrel steel tanks and five small portable working steel tanks of 5- to 35-barrel capacity provide oil storage. Electric power, gas, and water are provided by the Cities Service Co.

In treating the crude material, it is washed into a flume and heated to a liquid state by steam coils. It is then screened, a chemical destabilizer added, washed (desalted), mechanically settled, dehydrated, filtered, and run to storage. The oil is moved by steam and electrical pumps and gravity flow, but all oil lines are heated by a steam core to keep the oil liquid. The plant has an estimated capacity of three to five barrels of cleaned oil per hour.

Figure 7, an interior view of the processing building, shows, from left to right, the following major pieces of equipment: Heater, mechanical separator for oil and water, high-temperature dehydrator, filter, filter accumulating tank and vacuum and storage pump.

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Trial runs have necessitated many changes - in temperature control, in chemical destabilization of the already overtreated crude material, in mechanical operations, in flow lines, and, in protection against atmospheric conditions. Good progress is being made toward the goal of a continously operating unit controlled by two men per day of 8 hours. The product is a crude oil containing only traces of gasoline and kerosine, but the paraffin-wax content is concentrated to over 35 percent microcrystalline wax and 25 percent domestic paraffin.

There is an estimated annual accumulation of 3,000,000 barrels of waxy field-tank bottoms that is recoverable in the Mid-Continent area.

ANALYSIS OF CORES AND OIL-FIELD WATERS

The Petroleum and Natural Gas Division core and water laboratories were combined into one unit in 1944. Several new pieces of equipment were installed to increase the efficiency of the laboratory. Figure 8 shows the core-preparation table containing a laboratory rock crusher used in preparing core samples for determination of oil and water content, Di-met laboratory circular saw for cutting cores, and the drill press equipped with special drills for the preparation of porosity and permeability test specimens from field cores. In addition, there is shown a battery of 12 extractors used in the determination of oil and water content of oil-field cores. Other equipment in the laboratory includes two flow meters and a 50-inch manometer for the permeability apparatus, a 100-inch manometer to replace the dead-weight tester in the porosity apparatus, a rotameter, and an electric timer.

During the year, routine mineral analyses were made on 100 water samples. Porosity and permeability determinations and oil, water, and chloride analyses were made on 213 cores. A study was made to determine the advisability of substituting Selas filtering crucibles for filter paper and standard crucibles in the sulfate determination on water analysis. Many analyses were made by each method on a typical oil-field water in order to compare results. It was found that results obtained by filtering through the porous crucibles and oven-drying the precipitate satisfactorily verified those obtained by using filter paper and subsequently igniting the residues. Furthermore, these results are reproduced more easily, and considerable time is saved in the operation. Filtering crucibles were tried similarly as a substitute for filter paper in the calcium determination. The results of these determinations indicated that the two methods are comparable. The time required to complete analysis by either method is approximately the same. There appears to be less interference in the end-point when Selas crucibles are used, because filter paper reacts chemically to a slight extent with potassium permanganate. It was dicided that the filtering crucibles can be used advantageously in the sulfate determination, but that their use in the calcium determination is not warranted.

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Figure 8.-Core and water laboratory showing core preparation bench and battery of 12 extractors used in the determination of the oil and water content of oil-field cores.

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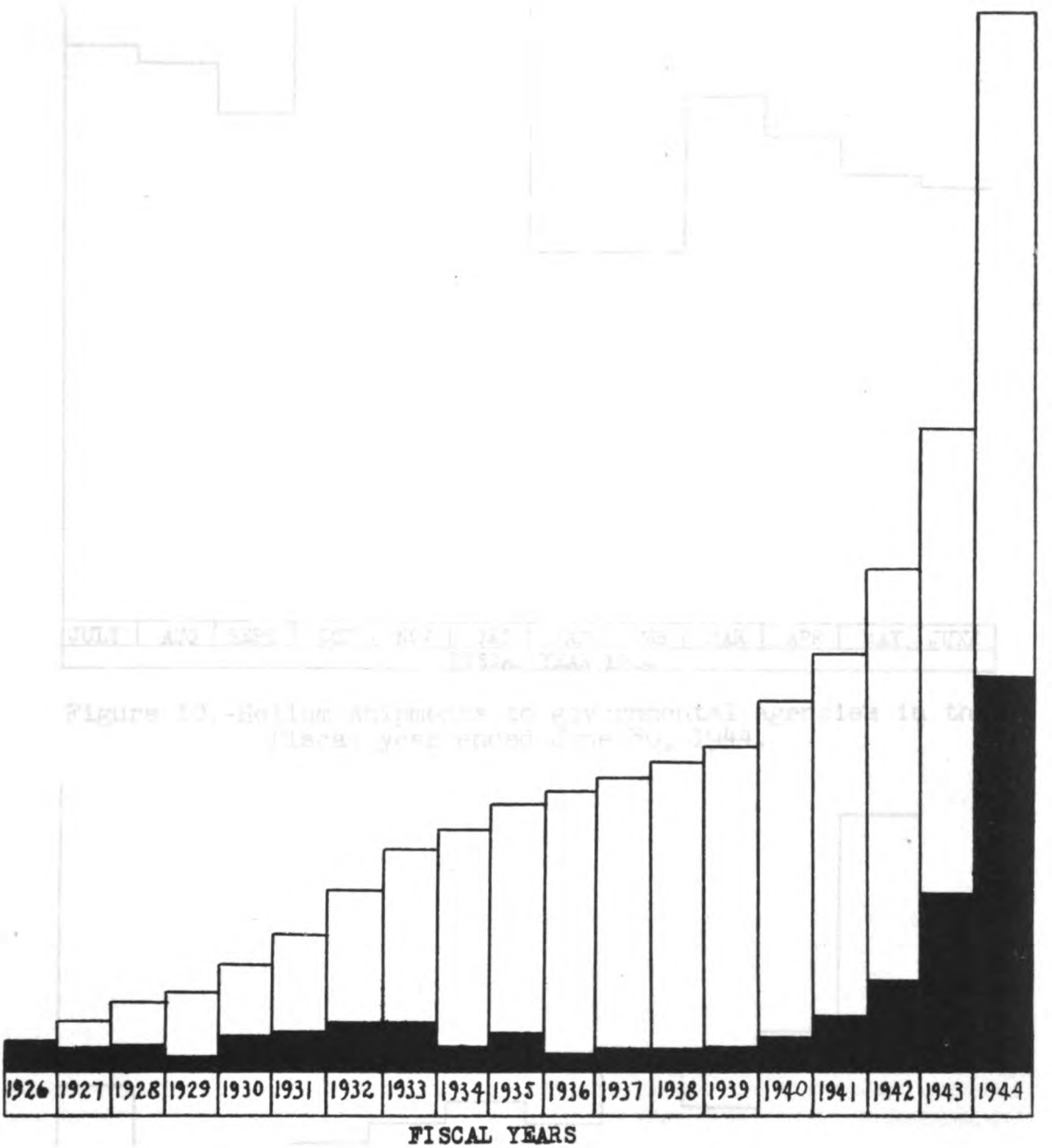

Figure 9.-Annual and cumulative production of helium by Bureau of Mines helium plants.

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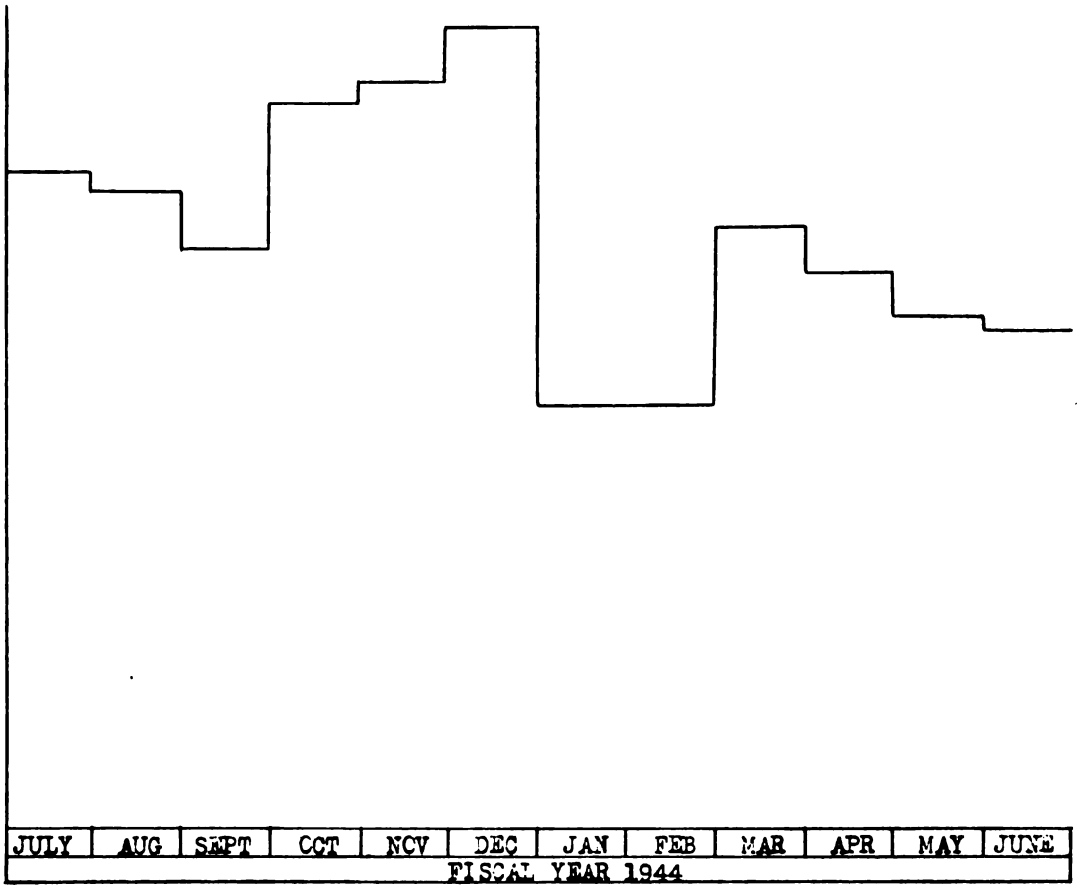

Figure 10.-Helium shipments to governmental agencies in the fiscal year ended June 30, 1944.

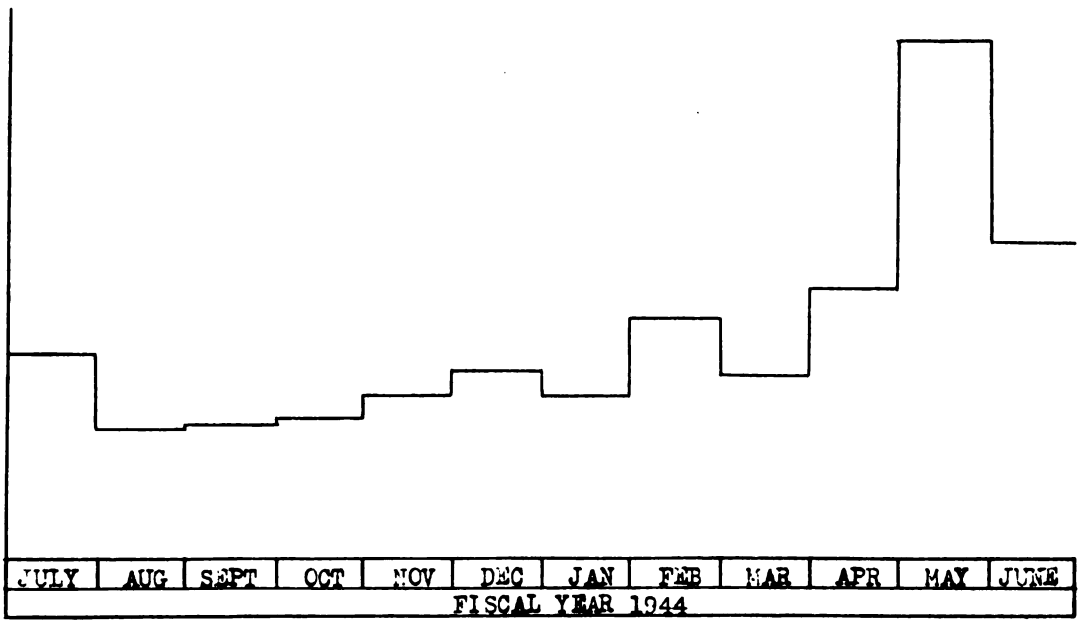

Figure 11.-Helium shipments to commercial (non-federal) users in the fiscal year ended June 30, 1944.

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PRODUCTION OF HELIUM

More than twice as much helium was produced by the Bureau of Mines during the fiscal year 1944 than was produced in any previous year. The production was eight times as great as the largest pre-war annual production.

Precise production figures cannot be released for security reasons, but the following tributes leave no doubts as to the sufficiency of the Bureau of Mines helium program:

> At no time during the present emergency has it been necessary to curtail Naval use of helium or to revise plans for use of helium because of shortages or prospective shortages of helium. (The late Frank Knox, Secretary of the Navy, on April 10, 1944, in a letter to the Secretary of the Interior.)

> ***not a single one of the thousands of ships under escort by blimps has ever suffered a successful attack by submarines. (Rear Admiral Charles E. Rosendahl, U.S.N., on January 19, 1944, on the occasion of the presentation of the Army-Navy "E" award to the employees of the Amarillo and Exell helium plants.)

NEW HELIUM PLANTS

New helium plants at Otis and Cunningham, Kans., and Shiprock, N. Mex., began producing in the fiscal year 1944. The total capacity of the Bureau of Mines helium plants is more than 25 times the pre-war annual production rate, and approximately 10 million cubic feet of helium per month can be made available to private industrial consumers. This is in addition to the volume supplied to the United States Navy and other governmental agencies.

RELATIVE RATES OF PRODUCTION AND CONSUMPTION

Because helium is a war material, accurate and detailed information on its production and consumption cannot be published. Figures 9, 10 and 11 are indicative, however, of the increased production and consumption rates. Each graph is plotted to a different scale, and units on the vertical ordinates have been deleted.

Figure 9 clearly indicates the increased rates of production of helium; figures 10 and 11 show the increased rates of consumption. The peak demands of the armed forces have been met, and helium consumption by governmental agencies has declined to a more or less constant rate. Of particular interest is the graph showing the increased volumes of helium shipped to commerical consumers.

USES FOR HELIUM

Helium-shielded arc welding accounts for most of the increased commercial consumption. The welding of magnesium and other light metals can

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be accomplished quickly and easily by this new welding method. Helium also is used to provide artificial breathing atmospheres in diving operations and as a diluent to prevent the explosion of anesthetics in operating rooms.

It is with sincere regret that details of the tremendous helium program of the Bureau of Mines are omitted from this report. However, two Army-Navy "E" flags - recognition by the armed forces of excellence in production of war materials - give ample evidence that the program is successful.

PUBLICATIONS

ISSUED IN FISCAL YEAR 1944

R. I. 3712 Analysis of Oil Production in the Near-depleted Mexia-Powell Fault-line Fields of Texas, by H. B. Hill and R. K. Guthrie. 1943, 83 pp., 30 figs.

R. I. 3715 Engineering Study of the Rodessa Oil Field in Louisiana, Texas, and Arkansas, by H. B. Hill and R. K. Guthrie, 1943, 126 pp., 51 figs.

R. I. 3719 Survey of Subsurface Brine-disposal Systems in Western Kansas Oil Fields, by Peter Grandone and Ludwig Schmidt, 1943, 20 pp. 1 fig. (In cooperation with Kansas State Board of Health.)

R. I. 3720 Magnolia Oil Field, Columbia County, Ark., Part I, Petroleum-Engineering Study, by Charles B. Carpenter and H. J. Schroeder. Part II, Derivation and Application of Material-balance Equation, by Alton B. Cook. 1943 115 pp., 22 figs. (In cooperation with Arkansas Oil and Gas Commission.)

R. I. 3721 Aniline Points of Hydrocarbons, by John S. Ball. 1943, 49 pp., 4 figs. (In cooperation with University of Wyoming.)

R. I. 3728 History of Water Flooding of Oil Sands in Oklahoma, by D. B. Taliaferro and David H. Logan. 1943, 182 pp., 54 figs. (In cooperation with State of Oklahoma.)

R. I. 3729 Restricted Publication. 1943, 16 pp. 2 figs.

R. I. 3735 National Motor-gasoline Survey, Summer 1943, by A. J. Kraemer and O. C. Blade. 1943, 28 pp. (In cooperation with Coordinating Fuel Research Committee, formerly the Cooperative Fuel Research Committee.)

R. I. 3744 Analyses of Crude Oils from Some West Texas Fields, by Boyd Guthrie. 1944, 45 pp.

R. I. 3758 National Motor-Gasoline Survey, Winter 1943-44, by O. C. Blade. 1944, 28 pp., 1 fig. (In cooperation with the Coordinating Fuel Reasearch Committee of the Coordinating Research Council.)

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Oil Shale as Source of Liquid Fuels, by A. J. Kraemer. Synthetic Liquid Fuels, hearings before the War Minerals Subcommittee of the Committee on Public Lands and Surveys, U. S. Senate, 78th Cong., on S. 1243. August 1943, pp. 303-318.

Oil-Shale Utilization, statements by A. J. Kraemer, Synthetic Liquid Fuels, hearings before the War Minerals Subcommittee of the Committee on Public Lands and Surveys, U. S. Senate, 78th Cong., on S. 1243. August 1943, pp. 298-436.

IN PRESS AT END OF FISCAL YEAR 1944

R. I. 3761 History of Water-Flooding of Oil Sands in Kansas, by Peter Grandone. July 1944, 146 pp., 52 figs. (Cooperation Kansas State Board of Health.)

REPORTS AND ARTICLES BY MEMBERS OF THE DIVISION THAT WERE PUBLISHED OUTSIDE THE BUREAU OF MINES OR PRESENTED BEFORE TECHNICAL SOCIETIES DURING FISCAL YEAR 1944

Some Tools and Methods Used in Cleaning Oil Wells in California, by G. B. Shea. California Oil World, August 1943, pp 6-11, 23. See, also, Bureau of Mines Report of Investigations 3706, 1943, 39 pp., 8 figs.

Bituminous Sands and Shales and Partly Subsurface Sands as Sources of Additional Oil in California, by G. B. Shea. California Oil World, December 1943, 1st issue, pp. 9-13. Presented before American Institute of Mining and metallurgical Engineers, Los Angeles, Calif., October 21-22, 1943.

Derivation and Application of Material-Balance Equations to Magnolia Field by Alton B. Cook. Part I, The Petroleum Engineer, February 1944, pp. 91-98, 19 figs., 20 tables. Part II, The Petroleum Engineer, March 1944, pp. 222-230. See, also, Bureau of Mines Report of Investigations 3720, 1943, 115 pp., 22 figs.

Portable Equipment for Measuring Properties of Fluids from Gas-Condensate Wells, by Kenneth Eilerts and others. American Gas Association Monthly, April 1944, pp. 148-152, 8 figs.

Aniline Points of Hydrocarbons, by John S. Ball. National Petroleum News Technical Section, May 3, 1944, pp. R 297, R 298, R 300-R 302, R 304-R 306. See, also, Bureau of Mines Report of Investigations 3721, 1943, 49 pp., 4 figs.

Natural Gas Research: Its Importance and Possibilities, by R. R. Sayers. American Gas Association Monthly, June 1944, pp. 247-251. Presented at Natural Gas Spring Conference, Natural Gas Department, American Association, French Lick, Ind., May 11, 1944.

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